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FIRST IN-ASIA DPMPL INVESTIGATIONS OF CLOUD-AEROSOL INTERACTIONS

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1. Introduction

Accounting for the effects of aerosols in Earth-atmosphere radiation balance and environmental pollution/air quality assessment is very complex and a challenging exercise. For several reasons, the study of aerosols and clouds has special significance over tropics where convective and high-altitude dynamical processes influence the distributions of aerosols. Thus the thermo dynamical forcing influences the aerosol patterns that are formed due to surface-generated aerosols especially during the early morning transition from a stable to convective boundary layer and vice-versa during the late evening transition.

Aerosol radiative forcings, both direct and indirect, are the most uncertain atmospheric forcings of climate change. Between them, the aerosol indirect forcing, that is related to the cloud radiative property changes through cloud-aerosol interactions. These interactions are believed to be the most plausible explanation for the observed decrease of the diurnal temperature cycle (Hansen et al., 1997). Hence detailed knowledge of aerosols and clouds is peremptory mainly for obtaining better radiative forcing estimates — one of the major uncertainties in understanding the influence of aerosols and pre-cursor gases on weather, climate change and underlying processes, and for refining models for improving satellite data retrieval algorithms. Moreover, the most important component that is missing so far in the tropical aerosol research is multi-dimensional mapping of aerosol properties and cloud structures during both day and night over different environments (associated with complex terrain and meteorological conditions). In this context, the **D**ual- **P**olarization **M**icro **P**ulse **L**idar (DPMPL) system at IITM, Pune would play a vital role in our understanding of **CL**oud-**A**erosol **I**nteraction **M**echanisms (CLAIM). This will also serve as very valuable input information to the weather, climate and air quality models (Holm et al., 2004; Kamineni et al., 2003; Beninston et al., 1990), those aimed at accounting for the radiative forcing and its impact on hydrological cycle on different spatial and temporal scales. The results reported in this paper include time evolution of boundary-layer structure and stratification and characterization of stratus clouds that occur during the monsoon season.

2. DPMPL and Data

The DPMPL at IITM is a portable, real-time observing system, and it comprises of mainly two parts. First part includes the transmitter (DPSS Nd:YAG laser with λ=532 nm, 20 μJ/pulse power @ 10KH$_z$, 2-50 KH$_z$ PRR, transmitter pulse width is 18.3 ns @2KHz PRR and data acquisition by the receiver at minimum pulse length of 2 ns corresponding to the finest range resolution of 0.3 m); alternate parallel and perpendicular

polarization at switching rate @ 2KH$_z$ laser PRR); receiver(14-inch Φ Schmidt Cassegrain telescope, 0.6 nm FWHM (or multi-FOV or Fabry Perot Etalon); utility electrical and electronics mounted on a vibration isolated platform on castor wheels in Thermo-electric cooled (TEC) and clean environment. The second part is a high reliability transportable control and data acquisition (~500 MH$_z$ sampling rate) processing Pentium computer. The transmitter-receiver axis alignment is achieved by means of octopus, which controls essentially the x and y axis of a mirror to align the laser beam with the receiver. A polarization rotator is used to flip the energy of each pulse at a particular frequency between the parallel and perpendicular states of polarization. Moreover, the complete system can be tilted by a few degrees for the vertical before acquiring the data to avoid specular reflection which might occur from horizontally oriented ice crystals during high-altitude cloud studies. Both are interfaced together through a set of cables that are terminated on respective connectors. This unique facility in Asia is expected to provide a variety of interesting and important information on aerosol-cloud interactions and their impact/feed-back processes on hydrological cycle and climate variability. More details about this newly-built compact lidar system and some first results are due to appear in the AMS Journal of Atmospheric and Oceanic Technology (Devara et al., 2007).

Figure 1 displays the DPMPL laboratory and inner view of the lidar system at IITM, Pune. The results reported in this communication pertain to more than 5000 one-minute lidar vertical profiles of backscatter intensity recorded during June-July 2007. Each profile has been corrected for background noise, range and also treated for air molecules due to Rayleigh scattering with values taken from the standard atmosphere (Sasi and Sen Gupta, 1986). These data sets are further subjected to the extinction coefficients (Fernald, 1964; Klett, 1981; Bhavanikumar, 2006) and linear depolarization ratio (Sassen, 1991) analyses.

Figure 1: Photograph depicting the DPMPL laboratory at IITM, Pune. The inner view of the lidar system is also depicted in the picture separately.

3. Stratus Cloud Characterization

(a) Profiling

As explained above, the raw backscatter signal strength profiles obtained with p- (parallel or co-polarization) and s- (perpendicular or cross-polarization) channels have been background noise corrected, and are shown plotted in Figure 2. Plot [A] portrays backscattered intensity up to 35 km at 3 m range resolution. In addition to exponential

decay (in the lidar return intensity), a strong echo from a two-layer low-level cloud around 4.5 km can be clearly seen in both || l and ⊥ r polarization channels on November 2005. The plot [B] depicts vertical profiles of backscatter intensity obtained with the parallel and perpendicular channels of DPMPL on July 15, 2007. Two stratus clouds, one around 400 m and the other around 1 km can be seen

[A] [B] [C]

Figure 2: Some typical profiles of lidar backscatter intensity from surface to stratospheric altitudes on different observational days from the figure. The plot [C] displays time evolution of two stratus clouds one above the other observed at an altitude of 600 m that commenced from 2143 hrs and lasted up to 2147 hrs, and the other one at an altitude of 1 km that persisted from 2147 hrs to 2153 hrs. Besides the sensitivity of both channels to multiple scattering, the ⊥ r polarization channel appears to be more sensitive to phase of the cloud. It may also be noted that the cloud echoes in this channel appear to be relatively broader, indicating polarization response to the transitions between the clear-air (aerosol) and cloud-air (cloud) environments.

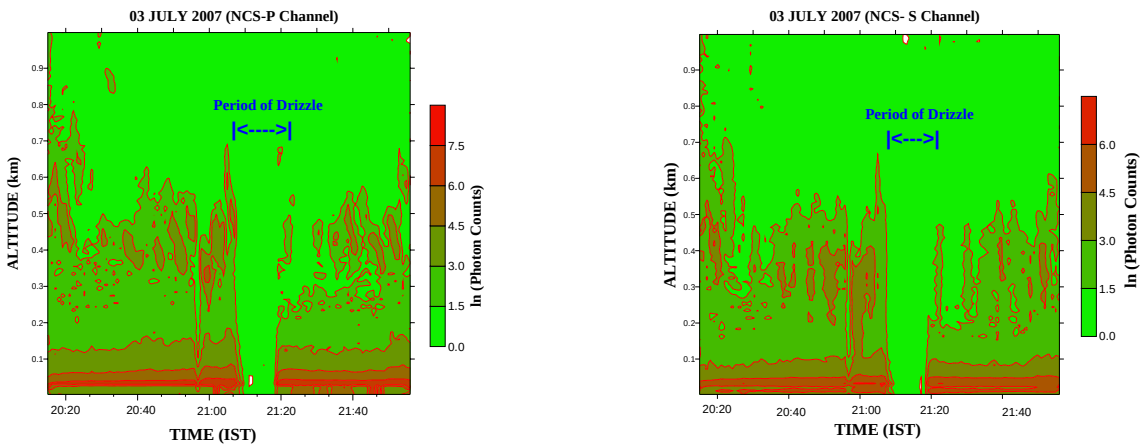

Figure 3: Time evolution of backscatter signal strength profiles recorded on July 03, 2007

(b) Height-time cross-sections of signal strength and depolarization

Figure 3 illustrates the time-height cross-sections of backscatter signal strength profiles obtained with p and s channels of DPMPL observed on July 03, 2007. They

clearly indicate evolution of nocturnal boundary layer, residual layer and stratus clouds observed with parallel and perpendicular polarization channels of the DPMPL on July 03, 2007. Gap in the observations from 2108 to 2118 hrs is due to occurrence of drizzle. Reduction in cloud activity followed by drizzle may be noted. The depolarization ratios (δ), corrected for air molecular effects, corresponding to the time-height cross-sections evaluated from the measurements made on 29 June and 03 July 2007 are shown plotted in Figure 4. The larger values of δ suggests abundance of non-spherical droplets.

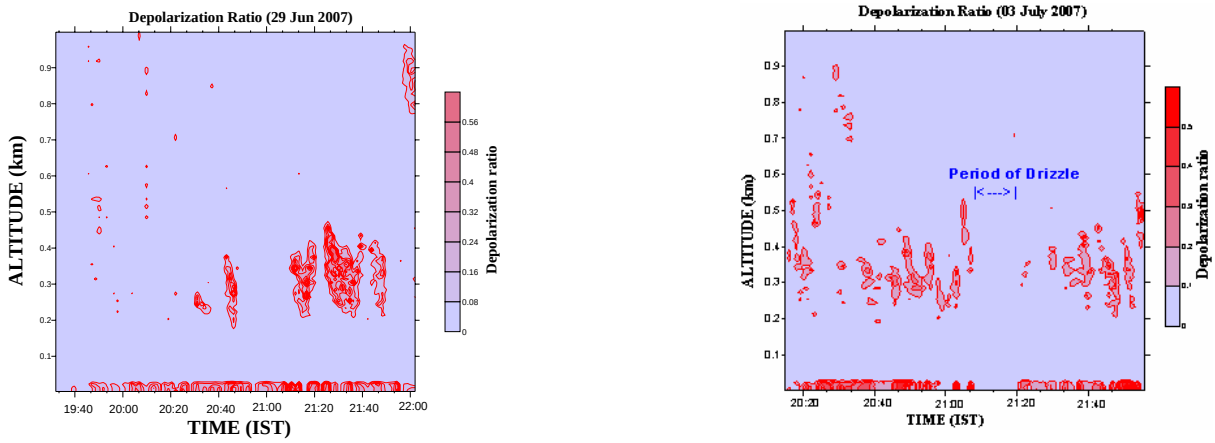

Figure 4: Time evolution of depolarization ratio of stratocumulus clouds observed on 27 June and 03 July 2007

4. Conclusions

The lidar observations reported here are being analyzed in conjunction with satellite IR images, synoptic wind field, tropospheric temperature/water vapor gradients, long wave flux and cloud amount/optical depth data for better understanding of the interplay between clouds and aerosols, and the impact of environment on such interactions. As the DPMPL data flow with high spatial and temporal resolution has begun on regular basis, and this lidar facility is being augmented with polarimetric Doppler Radar and many other complementary techniques in the coming years, more detailed studies on coupling processes between aerosols, clouds and climate in monsoon environment are planned in future work.

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